MICRONIC LASER SYSTEMS



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**International patent application No. PCT/SE2004/001701**
**Applicant: Micronic Laser Systems AB**
**Reply due: Sep 20, 2005**

**Reply to written opinion of March 11, 2005.**

Attached, please find a new set of claims.

Claim 1 has been amended to include "having a speckle pattern, which is a fine grained variation in illumination different from mode to mode and/or flash to flash" after "source" in line 2 of the preamble of the originally submitted claim 1. Support for said amendment can be found in the description on page 1 line 17-19. Claim 1 has further been amended to comprise "due to said speckle" inserted after uniformity in line 4 of the originally submitted claim 1. Support for said amendment can be found on page 1 in section 3.

Claim 4 has been amended to include "having a speckle pattern, which is a fine grained variation in illumination different from mode to mode and/or flash to flash" after "source" in line 2 of the preamble of the originally submitted claim 4. Support for said amendment can be found in the description on page 1 line 17-19. Claim 4 has further been amended to comprise "due to said speckle" inserted after uniformity in line 5 of the originally submitted claim 4. Support for said amendment can be found on page 1 in section 3.

Claim 5 has been amended to include "by using a partially coherent laser source having a speckle pattern, which is a fine grained variation in illumination different from mode to mode and/or flash to flash" after "CD-uniformity" in line 1 of the preamble of the originally submitted claim 5. Support for said amendment can be found in the description on page 1 section 3.

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Claim 6-8 have been amended to include "by using a partially coherent laser source having a speckle pattern, which is a fine grained variation in illumination different from mode to mode and/or flash to flash" after "CD-uniformity" in line 1 of the preambles of the originally submitted claim 6-8. Support for said amendment can be found in the description on page 1 section 3.

Claim 10 has been amended to include "having a speckle pattern, which speckle pattern is a fine grained random variation in illumination different from mode to mode and/or flash to flash" after light in line 2 of the preamble of the originally submitted claim 10. Support for said amendment can be found in the description on page 1 section 3. Claim 10 has further been amended to include "said" before "speckle" in line 12 of the originally submitted claim 10. Support for said amendment can be found in the description on page 1 section 3.

Claim 18 has been amended to include "having a speckle pattern, which speckle pattern is a fine grained random variation in illumination different from mode to mode and/or flash to flash" after light in line 2 of the preamble of the originally submitted claim 18. Support for said amendment can be found in the description on page 1 section 3. Claim 18 has further been amended to include "said" before "speckle" in line 9 of the originally submitted claim 18. Support for said amendment can be found in the description on page 1 section 3.

Claim 23-24 have been amended to include "which is a fine grained variation in illumination different from mode to mode and/or flash to flash" after "speckle". Support for said amendment can be found in the description on page 1 section 3.

Claim 25 has been amended to include "which speckle is amounting from fine grained variations in illumination different from mode to mode and/or flash to flash" after "speckle" in line 1 of the originally submitted claim 25. Support for said amendment can be found in the description on page 1 section 3.

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The examiner objects to the patentability by mainly making reference to citation D1 (US 4970546)

In D1 it is disclosed an exposure control device. An object as indicated in the summary is to provide an illumination control device capable of providing illuminating light with improved uniformity in intensity and without speckle fringes, by means of simpler structure. In the third paragraph under summary of the invention, there is a description in greater detail what kind of speckle one is trying to eliminate/minimize. Beginning on line 55 in said paragraph, "…for moving a speckle pattern, formed with a specific periodicity by the irradiation of a pulse (excimer laser beam)". Continuing in the same paragraph there is much talk about moving the speckle pattern substantially by a cycle. One is here talking about periodical speckle coming from the fly's eye lens, see first paragraph in section 3.

The present invention, according to the amended claims discloses a method and apparatus with improved CD for patterning a workpiece with partially coherent radiation having random speckle pattern.

In D1 a predetermined number of laser pulses are used to smoothing out the periodical pattern. On the contrary, in our invention one is using a number of laser flashes which will reduce the random speckle and thereby improve CD performance in a particular pattern on a layer by layer basis.

The examiner has founded that the novelty is lacking for all clais. Maybe it is worth wile to remind the examiner that novelty is destroyed ONLY if EVERY element in a patent claim can be found in a single cited document. Moreover, said novelty can only be destroyed if all features in a patent claim can be found in a single embodiment in said document. In D1, I fail to see that the number of laser pulses chosen will reduce random speckle pattern. What is disclosed in D1 is the reduction of periodical speckle pattern, which is not equivalent to random speckle pattern. Most likely one has to choose different number of laser pulses in order to achive the desired object. I also fail to see that one is choosing the number of laser pulses on a layer by layer basis. This invention allows a layer-by-layer trade off between troughput and printing fidelity. Lowering speckle on critical layers gives tighter CD control. Moreover, what is disclosed in D1 is coherent pulsed light, see for instance claim 1, we on the other hand are dealing with partially coherent radiation. For that reason I would be happy to know why the examiner is regarding claim 1, 11 and 29 as not novel?

Even if the skilled person would look into D1, said person would be unable to apply what is disclosed in said document in order to arrive to our claimed invention according to the amended claims. No disclosure in D1 is about reducing random speckle on a layer by layer basis for a partially coherent radiation source. What is disclosed is speckle reduction method for periodical speckle eminating form a coherent laser source for one layer only.

It is believed that this explanation make it possible to issue an overall positive preliminary report. If the examiner is of another opinion, we hereby respectfully request that contact is taken with the undersigned patent attorney in order to set a date for a personal interview (PCT Rule 66.6).

Täby, May 16, 2005
Micronic Laser Systems AB
IP Department

Johan Nordkvist

CLAIMS

1. A method to pattern a workpiece with improved CD uniformity using a partially coherent electromagnetic radiation source having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the actions of:
   - determining, for a plurality of layers in said workpiece, CD uniformity due to said speckle as a function of a number of exposure flashes,
   - determining, for a plurality of layers in said workpiece, the cost of patterning as a function of the number of exposure flashes,
   - selecting the number of exposure flashes on a layer by layer basis, which gives a predetermined CD uniformity corresponding to a preferred cost.

2. The method according to claim 1, further comprising the action of:
   - selecting a combination of values of the following parameters:
     - radiation bandwidth
     - pulse length
     - radiation flash frequency

   so that a calculated illumination non-uniformity (3 sigma) from speckle amounts to less than 0.5%.

3. The method according to claim 1 or 2, further comprising the action of:

- determining a value of a slit width so that a calculated illumination non-uniformity (3 sigma) from speckle amounts to less than 0.5%.

4. A computer assisted apparatus for printing a workpiece with improved CD uniformity by using a partially coherent radiation source having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, comprising:
   - logic and resources that determine, for a plurality of layers in said workpiece, CD uniformity due to said speckle as a function of the number of exposure flashes,
   - logic and resources that determine, for the plurality of layers in said workpiece, a cost of patterning as a function of the number of exposure flashes,
   - logic and resources that select the number of exposure flashes on a layer by layer basis, which gives a predetermined CD uniformity at a minimum of patterning cost.

5. A method for printing a workpiece with improved CD-uniformity by using a partially coherent radiation source having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the action of:
   - changing a number of exposure flashes per surface element on a layer by layer basis.

6. A method for printing a workpiece with improved CD-uniformity by using a partially coherent radiation source having a speckle pattern

which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the action of:

- changing a pulse length of exposure flashes per surface element on a layer by layer basis.

7. A method for printing a workpiece with improved CD-uniformity by using a partially coherent radiation source having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the action of:

- changing a radiation bandwidth of exposure flashes per surface element on a layer by layer basis.

8. A method for printing a workpiece with improved CD-uniformity by using a partially coherent radiation source having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the action of:

- changing a slit width of exposure flashes per surface element on a layer by layer basis.

9. The method according to any one of claims 5-8, wherein said changing is performed for critical layers in the microelectronic device only.

10. A procedure to improve CD uniformity of a layer exposed in a scanner or stepper using partially coherent light having a speckle pattern, which speckle pattern is a fine grained random variation in illumination different from mode to mode and/or flash to flash, including the actions of:

- providing a scanner system with an optical field larger than 10 mm,

- increasing one or more of the following parameters

a. slit width,

b. laser bandwidth,

c. pulse length,

d. laser flash frequency,

e. number of flashes,

f. number of flashes per field,

g. number of scan cycles per field

until the calculated illumination non-uniformity (3 sigma) from said speckle amounts to less than 0.5%.

11. The procedure as in claim 10 but with calculated speckle less than 1%.

12. The procedure as in claim 10 but with calculated speckle less than 2%.

13. The procedure as claimed in claim 10 but with calculated speckle less than 3%.

14. The procedure according to claim 10, wherein non-polarised light is used.

15. The procedure according to claim 10, wherein refractive optics is used.

16. The procedure according to claim 15, wherein at least one diffractive element is used.

17. The procedure according to claim 15, wherein catadioptric optics with at least one diffractive element is used.

18. A procedure to improve CD uniformity of a layer exposed in a maskless scanner using partially coherent light having a speckle pattern which is a fine grained random variation in illumination different from mode to mode and/or flash to flash comprising the steps of:

- providing a maskless scanner systems with an optical field larger than 0.5mm,

- increasing one or more of the following parameters:

a. laser bandwidth,

b. pulse length,

c. number of overlayed flashes,

until the calculated illumination non-uniformity (3 sigma) from said speckle amounts to less than 0.5%.

19. The procedure according to claim 18, wherein said calculated speckle is less than 1%.

20. The procedure according to claim 18, wherein said calculated speckle is less than 2%.

21. The procedure according to claim 18, wherein said calculated speckle is less than 3%.

22. The procedure according to claim 18, wherein non polarized light is used.

23. An apparatus for printing a workpiece with improved CD uniformity including:

- logic and resources to calculate speckle, which speckle is a fine grained random variation in illumination different from mode to mode and/or flash to flash,

- logic and resources that change the number of pulses per surface element on a layer to layer basis.

24. A procedure for optimizing speckle, which is a fine grained random variation in illumination different from mode to mode and/or flash to flash, during microlithographic printing including the actions of:

- providing a model for the value of improved CD uniformity,

- calculating the CD uniformity as a function of the number of flashes,

- providing a model for the cost of printing with a particular number of pulses,
- providing logic and resources that select a number of flashes that corresponds to a preferred result,
- providing a control adapted to change the number of flashes, and
- setting said approximately optimized number of flashes.

25. An electronic device with improved CD uniformity printed with speckle, which speckle is amounting from fine grained random variation in illumination different from mode to mode and/or flash to flash, less than 1% (3 sigma).

26. The method according to claim 23, further including the actions of:

- determining, for a plurality of layers in said workpiece, CD uniformity as a function of a number of exposure flashes,
- determining, for the plurality of layers in said workpiece, the cost of patterning as a function of the number of exposure flashes,
- selecting the number of exposure flashes on a layer by layer basis, which gives a predetermined CD uniformity corresponding to a preferred cost.

## ABSTRACT

An aspect of the present invention includes a method to pattern a workpiece with improved CD uniformity using a partially coherent electromagnetic radiation source. Said method including the actions of: determining, for a plurality of layers in said workpiece, CD uniformity as a function of a number of exposure flashes, determining, for the plurality of layers in said workpiece, the cost of patterning as a function of the number of exposure flashes, and selecting the number of exposure flashes on a layer by layer basis, which gives a predetermined CD uniformity corresponding to a preferred cost. Other aspects of the present invention are reflected in the detailed description, figures and claims.